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First Bipropellant Propulsion System for Spacecraft in Korea

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Abstract

In the framework of COMS (Communication, Ocean and Meteorological Satellite) programme, the first bipropellant propulsion system for GEO satellite has been developed successfully. So far Korea has its own experience of development of a monopropellant propulsion system for LEO satellites, i.e., KOMPSAT's. Other types of propulsion systems for a satellite, such as cold gas and electric propulsion etc., are being developed somewhere in Korea, however they are not commercialised yet, apart from those two systems aforementioned. This paper mainly focused on the design of the Chemical Propulsion System (CPS) for the COMS, joint scientific and communications satellite. It includes descriptions of the general system design and a summary of the supporting analysis performed to verify suitability for space flight. Essentially it provides an overview and guide to the various engineering rationale generated in support of the COMS CPS design activities. The manufacture and subsequent testing of COMS CPS are briefly discussed. Feasibility of COMS CPS to an interplanetary mission is proposed as well.

Introduction

The COMS mission[1-2] includes three main objectives, namely a meteorological service, ocean monitoring and Ka Band satellite communications. The system is organised around the space segment, which consists in a satellite placed on a geostationary orbit, and the various components of the ground segment. These elements are organized into a classical and sound architecture, which is able to meet the objectives of this mission.

The meteorological mission has the following goals:

- Continuous monitoring of imagery and extracting of meteorological products with high resolution and multi-spectral imager
- Early detection of special weather such as storm, flood, yellow sand, etc.
- Extraction of data on long-term change of sea surface temperature and cloud

The ocean monitoring mission aims at the following:

- Monitoring of marine environments around Korean peninsula
- Production of fishery information (Chlorophyll, etc.)
- Monitoring of long-term/short-term change of marine ecosystem

The objectives of the satellite communication mission are as follows:

- In-orbit verification of the performances of advanced communication technologies
- Experiment of wide-band multi-media communication service

Each of these missions is implemented within a distinct payload[3]. The Meteorological Imager (MI) and the Geostationary Ocean Color Imager (GOCI) are procured by the subcontractor, EADS Astrium; while the Ka Band communication payload is furnished by KARI. All three instruments are implemented on a geostationary satellite bus, with a strong heritage from the Eurostar E3000 product.

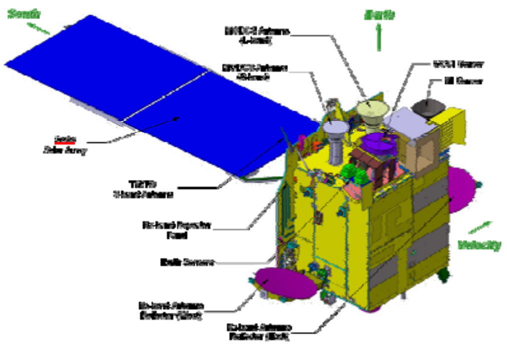

Fig. 1 Communication, Ocean and Meteorological Satellite

The raw image data generated by the Meteorological Imager and the Geostationary Ocean Color Imager are downlinked in L Band in real time by the MODCS function to the ground segment Meteorological/Ocean Data Application Center (MODAC), which is the primary Data Processing Center (DPC). This center generates calibrated image data as well as derived products and uplinks them in S Band back to the spacecraft, there again through the MODCS function. Data are then disseminated in L Band to regional users. This dissemination complies with the international HRIT / LRIT standard (High Rate and Low Rate Image Transmission) of the Coordinated Group of Meteorological Satellites. The processed meteorological and ocean data are also distributed to domestic end users through existing ground networks.

Satellite operation, mission planning and monitoring is performed by the Satellite Operation Center (SOC). This center is also designed to be used as a back-up functions for the DPC. Both the SOC and the MODAC will be interconnected by exclusive lines for data exchange and transmission.

The Ka Band communication payload provides mostly a repeater function and can therefore be operated independently from the other COMS payloads. The Communication System Monitoring Center (CSMC) monitors RF signals to check the status of Ka Band communication system and performs connectivity switching as required to fulfill the mission needs.

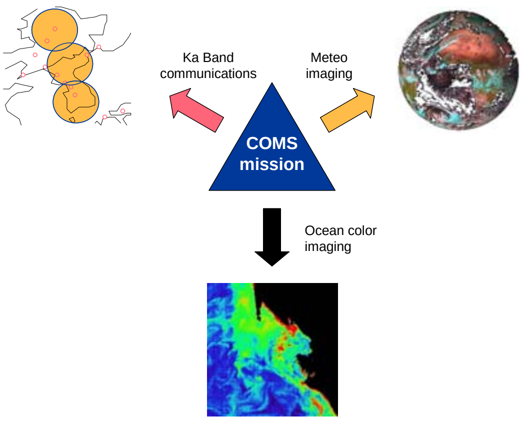

Fig. 2 Three-fold COMS mission

In terms of a propulsion system[4)], the COMS incorporates a chemical propulsion system which utilises bipropellant; the combination comprises MMH as a fuel and MON-3 as an oxidiser. In the framework of COMS implementation, COMS Chemical Propulsion System[5)] (CPS) has been separately developed in collaboration with UK company, the EADS Astrium Limited, Stevenage. The technology relevant to a bipropellant propulsion system is quite new one in Korea, which is transferred for the first time, with development of COMS propulsion system. It hasn't ever attempted before, and hasn't got any general idea itself as well, in Korea.

In this paper, therefore, the design, manufacture and testing of COMS CPS will be addressed. Feasibility of COMS CPS applicable to the other advanced mission shall be investigated as well.

CPS Design

The Chemical Propulsion System (CPS) is designed such that it will survive the pre-launch and on-orbit environments to perform both the orbital injection function, to take the spacecraft from transfer orbit to geostationary earth orbit, and can perform all on-station propulsive functions throughout the lifetime of the satellite. In a nominal mission, all station keeping manoeuvres are performed using the Chemical Propulsion System.

The COMS CPS will utilise the existing Eurostar design, development and manufacturing techniques generated as part of the Eurostar programme and further developed during the Eurostar 3000 Propulsion Development Programme.

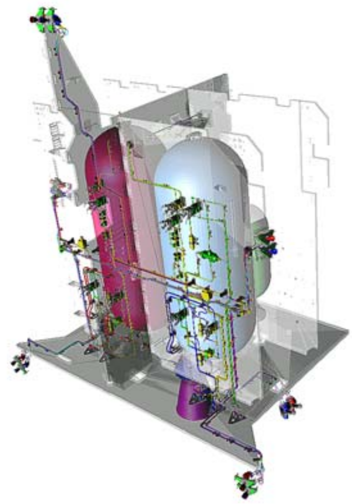

Fig. 3 COMS CPS layout

System Description

The COMS combined propulsion system is required to perform the following main functions,

- Orbit raising from GTO to GEO orbit, through the use of a main engine
- Attitude determination and control throughout mission life

The COMS CPS schematic is defined below.

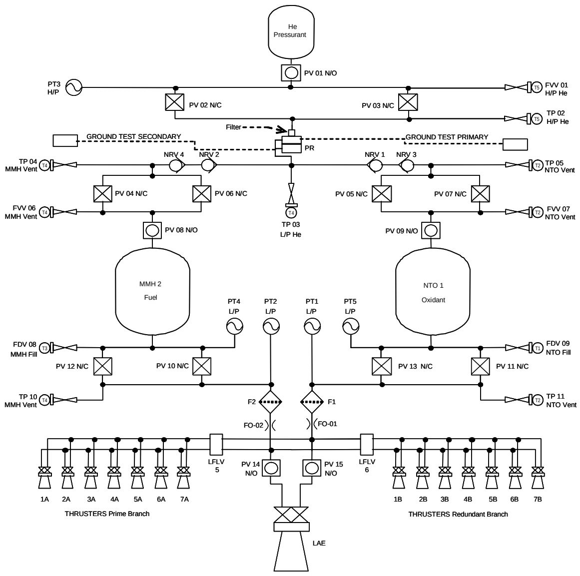

Fig. 4 COMS CPS Schematic

The COMS chemical propulsion system is a Helium pressurised bipropellant system using monomethyl hydrazine (MMH) as the fuel and mixed oxides of nitrogen with 3% nitric oxide (MON-3) as the oxidant. A common propellant storage and feed system supplies the liquid apogee engine (LAE) and the reaction control thrusters (RCTs).

The system is designed to operate in a constant pressure mode during the LAE firings using a regulated helium supply. Following completion of the orbital injection manoeuvres, the regulated helium supply and the LAE are isolated. The remaining propellant is supplied to the RCTs in blowdown mode. This is to maximise reliability by providing a major system simplification.

The COMS CPS baselines heritage components, design philosophies and techniques developed for the Eurostar satellite fleet. The COMS CPS has been designed to re-use the same sub-system equipments that have been flight proven for telecommunications applications through the many Eurostar missions.

The overall design of the COMS mission is very similar, in structure, to the missions of Mars Express and Venus Express, scientific missions. The design approach for the CPS on these platforms is therefore very similar to that which we are required to use for COMS.

System Performance Analysis

The analyses described within this section shall be performed using specific analysis software, originally developed for the Eurostar programme. The software is adaptable for many different types of CPS mission, propellant types and tank configurations. The final analysis shall be prepared using values form the acceptance tests of the subsystem components as delivered, to produce an accurate CPS analysis.

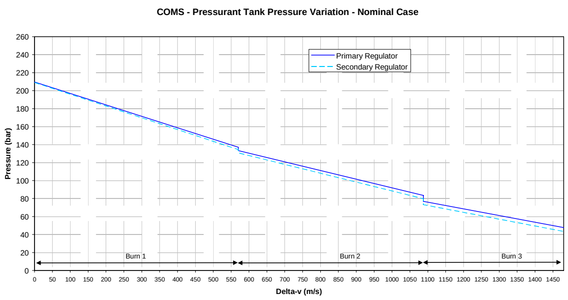

Fig. 5 Use of Pressurant during the Transfer Orbit

In order to analyse the pressurant system under various mission conditions, a mathematical pressurant system model has been produced. The basic model has been validated during the Eurostar Development Test Programme and using flight data from Eurostar launches. The use of pressurant during the transfer orbit is shown in below in Fig. 5.

In order to predict the propellant flow effects on the CPS performance, a mathematical flow model has been produced. The basic model has been verified against the Eurostar development model test programme. Flight specific analyses have been performed for COMS using COMS specific pipework geometry and component acceptance test data. Mission analyses were provided for Ariane5, Nominal and Cold case (backup) which allow us to see the results of the best and worst case launches we can expect.

The LAE mathematical flow model determines the flow loss characteristics through the system, calculates the orifice sizes required to balance the propellant tank outflows and predicts the possible influence of system temperature and pressure on LAE performance in terms of nominal and random elements for mixture ratio, mass flow rates, thrust and specific impulse. These in turn can be used to predict the nominal propellant consumption and the possible random consumption associated with a particular burn.

The RCTs are supplied having first been acceptance tested within a specified pressure box. Throughout on station operation, the RCTs must operate within this defined box. An analysis of the pressures was conducted using the specific computer program. Fig. 6 below plots the results of this analysis which clearly shows that the RCTs are predicted to operate within the acceptance limits provided the temperature range remains within the predicted ranges for on-station operation.

The overlapping series of crosses in this figure signifies the predicted operating points of the thrusters through life.

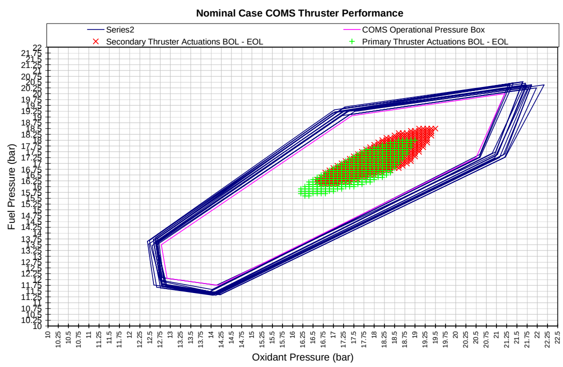

Fig. 6 COMS – On-station pressures Nominal Case

CPS Manufacture, Integration and Testing

The manufacturing process of the CPS is all conducted under controlled clean room conditions. Each stage is clearly defined below.

Preparation Activities

A number of tasks are completed in preparation for the delivery of the structure. These should all be finished and ready for installation on receipt of the structure.

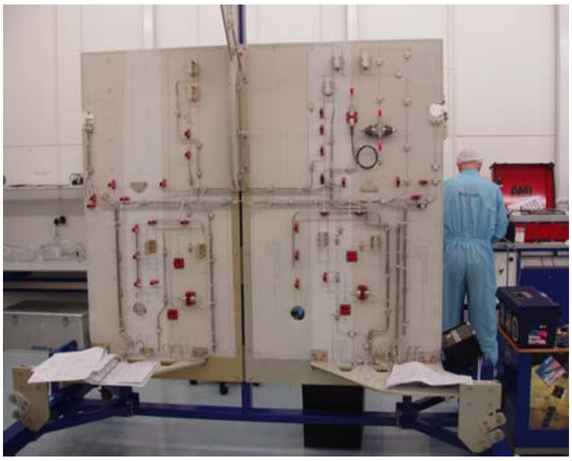

Fig. 7 CPS Pipework and Component Welding

Integration Activities

Once the structure arrives and all preparation activates are complete, the integration of all equipments onto the structure can begin.

Once all harness has been routed behind propellant tank locations the propellant tanks are mechanically installed. They can be welded into the rest of the CPS. the final two Test Ports are then also integrated in the CPS as well. Tank harness can then be routed out joined in with relevant circuits and taken to the allocated connector brackets.

The Westcott proof test can then be conducted. This is completed off site and the structure is away for approximately one week.

Fig. 8 CPS High Pressure Test in Westcott

After the CPS Delivery Review Board (DRB), the manufacture and testing of the CPS were successfully authorised to dispatch the COMS structure to Korea. The FM (flight model) CPS assembly[6], as shown in Fig. 9, has been delivered to KARI at the end of August last year. Currently, the COMS satellite is in KARI facility for the system integration and test.

Fig. 9 COMS CPS in KARI facility

Conclusion

The Analyses performed to show that the CPS is fully capable of fulfilling the needs of the COMS mission. Manufacture and testing of the CPS were successfully accomplished, and COMS CPS assembly was transported to KARI to perform S/C level integration in Korea.

The bipropellant propulsion is the strong candidate to make spacecraft fly toward the moon. Therefore the development of COMS CPS must be the cornerstone of the advanced propulsion system in Korea, for a future spacecraft being assigned for interplanetary mission.

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